Acoustics of Underwater Sediments

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LONG-TERM GOAL

The long-term goal of this research is to understand environmental effects on acoustic propagation to and scattering from a known object buried in the ocean bottom.

OBJECTIVES

Enhanced acoustic transmission into sandy ocean sediments has been observed when a sound field incident on the bottom impinges at grazing angles below critical [1,2] but the mechanism for the enhancement is not clear. Of particular interest here is a mechanism suggested by researchers from the Applied Physics Laboratory at the University of Washington (APL/UW) [3], who propose small-scale surface roughness can enhance acoustic penetration by diffracting energy down according to the spatial wavelengths exhibited by the roughness. The goal of this work is to isolate and quantify the role of ocean bottom roughness on the transmission process and understand its implications to modifying the acoustic response of an object buried at extended ranges from an acoustic source.

APPROACH

The work summarized here represents the second year in an investigation of rough bottom effects using theoretical and laboratory-scale experimental tools. During the first year (FY97), an extension of the roughness diffraction mechanism was pursued in collaboration with APL/UW researchers to develop a scattering solution that could predict the average response of a target buried in a layered fluid environment, including the effects due to random surface roughness. This was accomplished by combining Rayleigh-Rice perturbation theory (as formulated by Moe et al. [3] to describe roughness effects) with transition-matrix descriptions of scattering by a buried spherical target.

Concurrent with the theoretical developments, a laboratory tank experiment was devised and set up to quantify and understand transmission anomalies attributable to the roughness diffraction mechanism. Here, the approach involves projecting sound through an artificially roughened interface between two immiscible fluids. The fluids chosen, vegetable oil and glycerin, are poured into a 4’x4’x7’ wooden tank and, after they phase separate, the interface is roughened by floating polystyrene beads of various sizes between the fluids. Pulses generated by a 100-250kHz piston transducer mounted from a

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movable platform over the tank are recorded at an array of hydrophones set up in the lower fluid. Data are analyzed using tools similar to those adopted by Chotiros [1], but modified to allow for well over-sampled data sets and averaged over bead ensembles to facilitate comparisons with theoretical predictions.

WORK COMPLETED

A paper describing the scattering solution formulated and numerically implemented in FY97 for a spherical target buried under a randomly rough interface [4] was written and submitted for publication. Preprints are available upon request.

Transmission data from the tank setup described above have been collected for a large number of bead configurations (including the case with no beads), 3 bead sizes (3/32”, 3/16”, 1/4” diam.), a large number of source incident angles (by tilting the transducer), several source positions (by translating the transducer), and over source frequencies of 100-250kHz in 15kHz steps. To help interpret the results, a simple time-domain simulation of the field transmitted through the roughness and received at a given hydrophone was devised and numerically implemented. The simulation helped to assess a number of unknown variables in the measurements; e.g., the effect of wall reverberations, different bead arrangements, scattering effects intrinsic to the beads, spherical spreading effects neglected in the processing, effects caused by the beam pattern of the transducer, ensemble averaging effects, etc. Both measured and simulated tank data have been processed to quantify the level of transmission and the apparent propagation speed and angle of the transmitted wave front.

RESULTS

The tank data exhibited a number of effects worth mentioning. Enhanced shallow-grazing-angle transmission due to roughness diffraction was demonstrated, although a dependence on the roughness height as set by the bead size was evident. This is illustrated in Fig. 1, where the intensity transmitted to one of the hydrophones (#3) in the glycerin is plotted as a function of time delay and beam grazing angle for a 100kHz center-frequency, 100• s duration pulse. Here the source transducer was placed so that a line from the source to a spot on the interface above the hydrophone is slanted 18^o from the interface and the beam grazing angle was varied by tilting the face of the transducer. When the beam is tilted directly at the hydrophone the beam angle is well below the critical grazing angle for the fluids used, which is about 40^o. The hydrophone is about 12 cm below the oil/glycerin interface, which is well below the evanescent zone for the frequency band of the pulse. The beads were placed on the interface in a regular pattern meant to optimize diffractive scattering at 100kHz. Nevertheless, very little difference compared to the clean interface transmission is shown for the small beads. But, as the bead size is increased, energy transmission is definitely enhanced at extended times and shallow angles. Recorded signals representing this energy are typically quite elongated and exhibit little spatial coherence when compared to signals recorded at the other hydrophones.

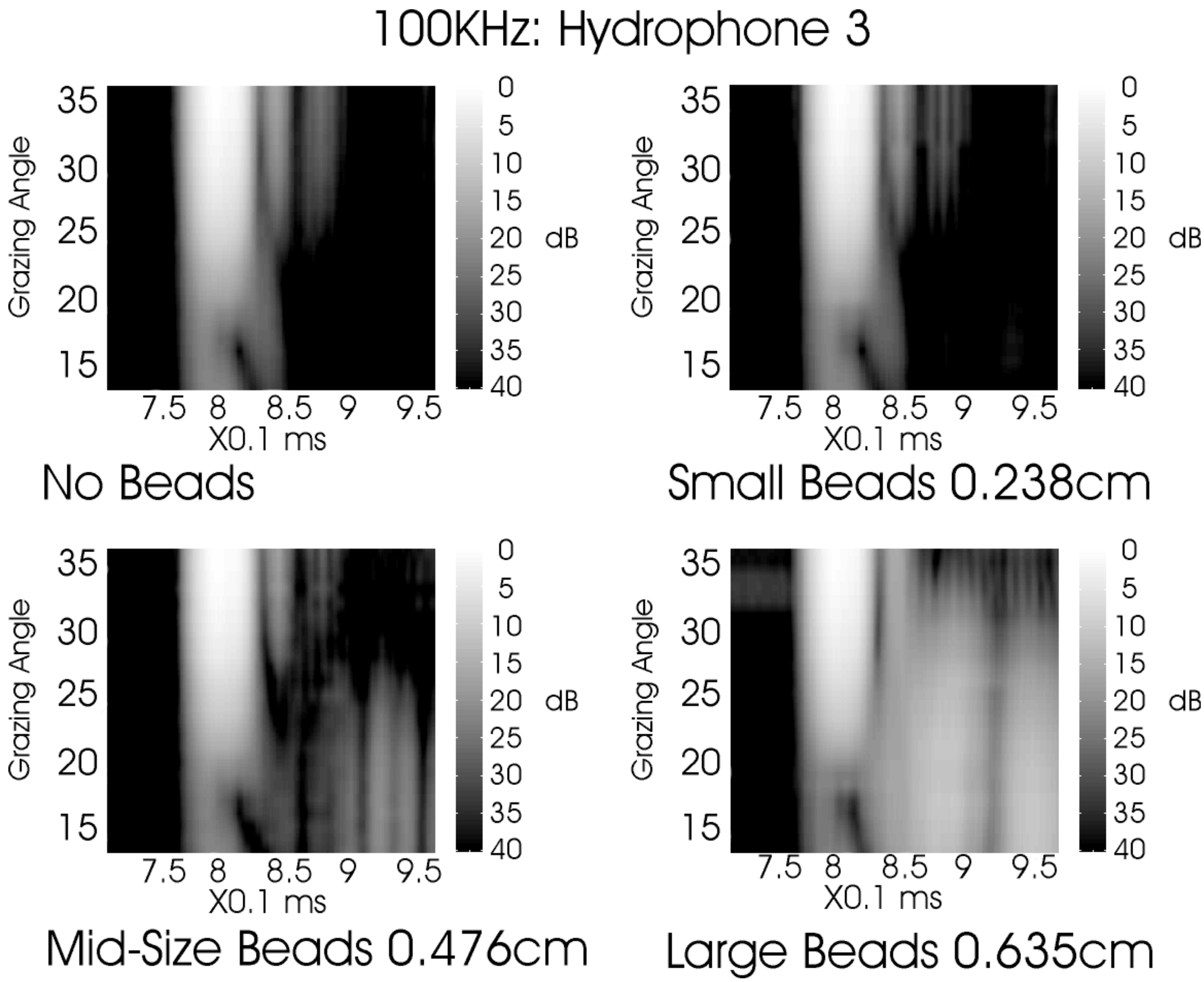

Figure 1. Transmission intensities recorded at hydrophone #3 in the glycerin layer.

Because of the low spatial coherence, it was difficult to determine a distinct direction of propagation and apparent speed for the signals that pass the hydrophone array when associated with a single incident pulse. However, averaging over data collected from an ensemble of bead arrays (obtained by stirring the beads) allowed a determination of the average direction of propagation and apparent speed. This determination is illustrated in an ambiguity plot in Fig. 2 for transmission through arrays of the 1/4" beads, where the maximum intensity indicates the associated direction and speed. A comparison with simulated data averaged over an ensemble of uniformly distributed beads is also shown in Fig. 2 for transmission of 100kHz pulses. Here it is noted that, in order to obtain agreement with the tank data, the bistatic scattering pattern of the individual beads had to be incorporated into the simulation. This agreement is remarkable because both the direction and apparent speed exhibited in the ambiguity plot for the tank data are different from the predictions that would be made by simply using a Bragg scattering condition and assuming omnidirectional scattering from the beads; the Bragg predictions would have been 39^o for the apparent propagation angle and 1200m/s for the apparent speed. Thus, the directionality of the scattering by roughness features can be an important consideration when predicting penetration effects.

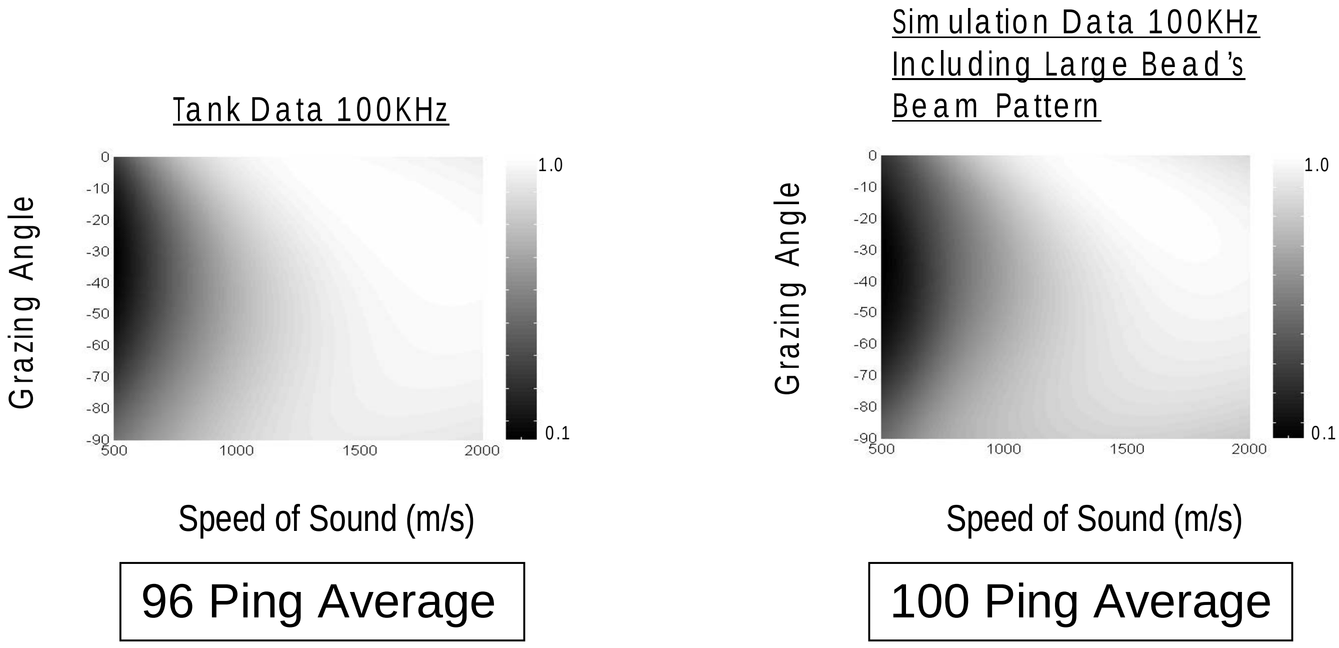

Figure 2. Comparison of ambiguity plots for data from tank measurements and simulations.

IMPACT/APPLICATIONS

This work will aid the development and optimization of bottom searching sonar for meeting the Navy's coastal missions, including mine-countermeasures, environmental reconnaissance/surveillance, and ordnance disposal.

TRANSITIONS

The results of these experiments are being used to aid design and testing of handheld sonars being developed under 6.2 SPECWAR funding for buried mine detection.

RELATED PROJECTS

The present project was leveraged in FY98 by funding from ONR's Navy Laboratory Participation Program, the CSS Independent Research Program, and ONR's SPECWAR Program.

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